Carleton (C. M.)

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Chas. M. Carleton.

THE

USE AND ABUSE

OF

SPECTACLES

BY

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THE

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OF NORWICH.

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ERRATA.

Page 8, line 16, for opthalmometre *read* ophthalmometre.
" 15, line 6, for P_2 *read* presbyopia.
" " lines 29 and 36, also page 16, line 6, for opthalmoscope *read* ophthalmoscope.
Page 20, line 35, for covergent *read* convergent.

THE USE AND ABUSE OF SPECTACLES.

There are few subjects connected with the practice of medicine and surgery more important or less understood, by the mass of the profession, than the selection of spectacles. Our knowledge of the affections of the eye, arising from the anomalies of refraction and accommodation, has been greatly increased during the last few years. Many diseases which were formerly considered incurable, are now found to be perfectly amenable to treatment. This change is due chiefly to the researches of Helmholtz, Von Graefe, Donders, Bowman, Liebreich, Wecker, and a few others. Their zeal has been untiring, and the world, as well as the profession, owes them an endless debt of gratitude.

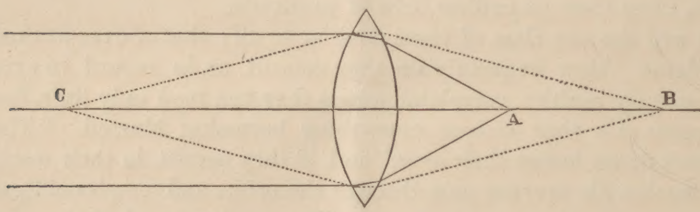
I will cite one class of cases familiar to all; that of over-worked students. How frequently do they consult us, in regard to eyes apparently healthy, complaining that they can read only for a few minutes at a time without everything becoming blurred. "The letters dance before their eyes," and, if they persist in their work, an intolerable nervous pain through the orbits and temples obliges them to close their eyes and rest. They anxiously ask if they are in danger of becoming blind. This question was, formerly, very frequently answered in the affirmative. The patient was condemned to wear green glasses or a shade, to go out of doors only after sundown, and on no account allowed to use his eyes for reading or any fine work for a period of six months or a year. The disease was variously called Irritability of the Retina, Retinitis, Choroiditis, Incipient Amaurosis, &c., &c. Donders has demonstrated beyond a question that this troublesome affection (Asthenopia) is, in nearly all cases, due to Hypermetropia and easily cured by the proper use of glasses, without loss of time to the patient while under treatment.

Spectacles should in all cases be selected by an oculist, or at least by a physician possessed of specific knowledge on the subject. A case of trial glasses, consisting of a complete set of convex and concave spherical and cylindrical lenses, prisms, tinted glasses, and stenopaic apparatus, is an indispensible requisite. No jeweler or mere optician should ever be entrusted with so delicate and important a task. An injudicious selection frequently ruins eyes that might by proper treatment be rendered useful. To make a proper selection of glasses in any and all cases, it is necessary that the practitioner should thoroughly understand: 1. The properties of optical lenses. 2. The eye as an optical instrument. 3. The anomalies of refraction and accommodation of the eye. Let us consider these in their numerical order.

THE PROPERTIES OF OPTICAL LENSES.

The lenses in most general use as aids to vision are the spherical biconvex and biconcave, with the radii of curvature of the two surfaces equal. Rays of light passing through the centre of either of these lenses are not deflected. Parallel rays, emanating from an object at an infinite distance* falling upon a biconvex lens are united at a certain point behind the lens (A, Fig. 1,) which point is called the focal point or principal focus.

Fig. 1.

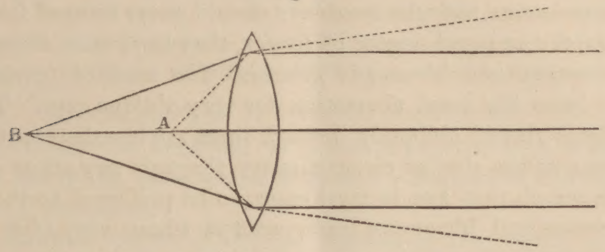


The focal distance of simple biconvex and biconcave lenses is nearly equal to the radius of curvature of the lens. The fact that convex and concave lenses of equal power exactly neutralize each other, furnishes us with an easy method of determining the power of any given lens. Thus if the lens be convex, we neutralize it with a concave lens from the trial case, and the number of the concave glass will give that of the convex.

* An object is considered, by oculists, to be at an infinite distance when the rays emanating from it fall upon the eye so nearly parallel that the divergence is imperceptible, which obtains at a distance of about eighteen or twenty feet.

Convergent rays are brought to a focus at a point (A. Fig. 2,) between the principal focus and the lens.

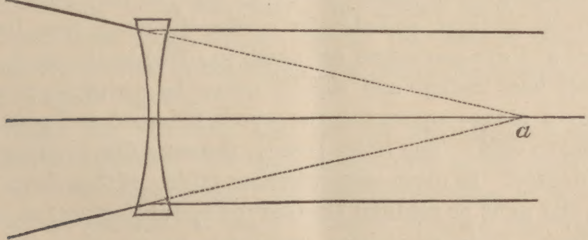
Fig. 2.



Divergent rays are brought to a focus at a greater distance from the lens than the principal focus, unless they emanate from an object situated at the same or a less distance from the lens than the principal focus, when the lens will only have the power of rendering them parallel or less divergent. (See Fig. 2.) Rays emanating from an object at twice the focal distance from the lens, are brought to a focus at the same distance on the other side of the lens. Rays emanating from an object situated at B (Fig. 1,) are brought to a focus at C. If the position of the object be changed to C, rays emanating from it will be brought to a focus at B. Any two points thus dependent upon each other, are called conjugate foci.

Biconcave lenses render parallel rays divergent. On leaving the lens they assume a direction as if they emanated from a point nearer the lens. Parallel rays passing through a biconcave lens of six inch focus appear to emanate from a point six inches in front of the lens. This point, (Fig. 3, *a*) where the deflected rays, if prolonged backwards through the lens, would intersect each other, is called the negative virtual focus. It is an imaginary one being situated on the same side of the lens as the object.

Fig. 3.



Divergent rays, emanating from an object at a finite distance, are rendered more divergent, and have their imaginary focus nearer the lens than the principal focus.

Beside the glasses described above we have the concavo-convex or positive meniscus, convexo-concave or negative meniscus, the cylindrical convex and concave lenses, prisms, and tinted glasses. The plano-convex and plano-concave should never be used for spectacles, as, for an equal degree of power, they have more aberration than biconvex and biconcave glasses. The menisci (periscopic glasses) have the least aberration for very oblique rays. Therefore objects viewed obliquely through them are less distorted than when seen under similar circumstances through any other glass. For this reason they are, in most cases, to be preferred to the simple biconvex and biconcave lenses, except where very high power is required, when their greater weight is a disadvantage.

All the lenses described thus far are spherical lenses; i. e. they are segments of spheres and refract equally all rays which fall upon them in all the planes of the segment. Besides these it is frequently necessary to have recourse to cylindrical lenses; i. e. lenses which are segments of a cylinder and which refract those rays strongest, which fall upon them in a plane at right angles to the axis of cylindrical curvature. The refraction grows less and less towards the cylindrical axis, at which point none occurs.

In certain forms of impaired vision, prisms are indicated rather than lenses. It is sometimes necessary to combine the two. The action of the prism is to refract all rays passing through it towards its base.

Tinted glasses are used for modifying the light, in cases where ordinary daylight cannot be endured. Green glasses were formerly recommended on the supposition that the red rays of the solar spectrum were those which irritated the retina. It is now a settled fact that not the red but the orange rays have this effect. Blue excludes the orange rays, and is, therefore, the proper color to be employed. Furthermore as blue occupies a more excentric position in the solar spectrum, it makes less impression upon the retina. Smoke-glasses should never be used, as they diminish the whole volume of light, and thereby render the image less distinct.

Goggles and eye-protectors are much too frequently used. The former over heat the eye and should never be worn except when, soon after a severe operation, the eye is inflamed and peculiarly susceptible to cold. The latter possess the same disadvantage, but in a less degree. In most cases where anything of this character is required, the light or medium blue curved eye protectors (*coquelles*) are the best. It is sometimes necessary to combine the blue tint with a refracting power. If the power required be low, the

lens may be cut from tinted glass, but in high powers the varying thickness of the lens causes a considerable difference in the tint, in the centre and at the edges of the glass, which confuses the vision. In such cases Mr. Laurence, of London, recommends the joining of very thin plates of tinted glass, by means of Canada balsam, to the backs of plano-concave and convex lenses.

THE EYE AS AN OPTICAL INSTRUMENT.

The eye may be regarded as a camera obscura with a concave screen, the retina, upon which is formed a diminished and inverted image of the object.

The dioptric system of the eye consists of the cornea, aqueous humor, crystalline lens and vitreous humor; conjointly they act as a biconvex lens, and bring parallel rays, in the normal eye, to a focus upon the retina. The cornea and aqueous humor may be considered as presenting only one refracting surface, on account of the parallelism of the two surfaces of the cornea, and the fact that the two media possess very nearly the same refractive power. The refraction of the vitreous humor is nearly the same as that of the aqueous. The lens is by far the most powerful refracting medium in the eye, without it parallel rays would not be brought to a focus upon the retina but behind it.

The optic axis is an imaginary line (*a b* Fig. 4) drawn from the centre of the cornea to a point lying midway between the optical disc and the macula lutea.

Fig. 4.

The visual line is an imaginary line drawn from the object to the macula lutea (Fig. 4 *c*, *d*,), for as the macula lutea is the most sensitive portion of the retina, it is always, in the normal eye, directed towards the object.

The visual line and optic axis are not, therefore, identical, as was formerly supposed, but cross each other at the nodal point (*k*, Fig. 4). The angle formed by their intersection at the nodal point is, in the normal eye, one of about 5 degrees. In hypermetropic eyes it is greater, often amounting to 8° or 9° which gives

rise to apparent divergent strabismus. In myopia it is less, or the two lines may even be identical. The nodal point, where all the rays of direction cut each other, is situated in the lens near its posterior surface (Fig. 4, *k*,).

We come now to treat of the accommodation of the normal eye. Parallel rays, emanating from an object at an infinite distance, falling upon the normal emmetropic eye, when at rest, are brought to a focus on the bacillar layer of the retina. Now if the object be brought nearer to the eye the rays emanating from it will become divergent, and will not be brought to a focus upon the retina but behind it, unless the refracting power of the eye be increased.

Many theories have been advanced as to what changes the eye undergoes in the accommodation for near objects. Some have claimed that the cornea becomes more convex; but Helmholtz has proved, by his opthalmometre, that the cornea undergoes no change during accommodation. Others have thought that the recti muscles, by changing the form of the ball, assist in the accommodation, but in a case reported by Von Graefe, where all the recti and obliqui muscles were paralyzed, so that the eyes were perfectly immovable, the accommodation was perfect.

At about the same time, Helmholtz and Cramer (working independently of each other) demonstrated the fact, that the change in the refraction of the eye during accommodation is wholly due to an alteration in the form of the lens. Helmholtz found that the lens did not change its position, but that the convexity of its two surfaces was increased, thereby shortening its focal distance. He found by calculations that these changes were sufficient for all accommodative purposes.

On holding a lighted candle before the eye during accommodation for near objects, the reflex image from the cornea remains unchanged, whilst that from the anterior surface of the lens diminishes in size and approaches the corneal image; the image from the posterior surface of the lens diminishes slightly in size, but does not change its position.

The next question necessary to decide is, how this change in the form of the lens is produced. The changes have been considered as the result of the combined action of the iris and ciliary muscle. Some physiologists giving the preëminence to the iris and others to the ciliary muscle. Cramer thought the change was brought about through the agency of the iris, the ciliary muscle

acting only as a support to the lens, preventing its dislocation backwards under the pressure of the iris. Donders agrees for the most part with Cramer, but says further: "I consider the ciliary muscle just as important for the change in the form of the lens as the muscular fibres of the iris; without it the iris would not be able to exert a pressure of any importance upon the lens." Helmholtz gives more importance to the action of the ciliary muscle than either Cramer or Donders, but considers that the iris plays the most important *rôle* in changing the form of the lens. Heinrich Müller, on the other hand, attaches greater importance to the action of the ciliary muscle than to that of the iris.

It has fallen to the lot of Von Graefe to decide this important question. A case occurred in his clinique in which, after the removal of the entire iris, the power of accommodation remained unimpaired, but became paralyzed, on paralyzing the ciliary muscle, by the instillation of a strong solution of atropia.

RANGE OF ACCOMMODATION.*

By this term is understood the distance between the farthest and nearest points of distinct vision. In the normal eye, at puberty, the nearest point of distinct vision lies at about $3\frac{1}{2}$ or 4 inches from the eye, and the farthest at infinite distance. These limits vary with the age of the patient. In determining the situation of the near and far points, the size of the object must be considered, as well as the distance at which it can be seen. An object cannot be distinctly seen under an angle of less than five minutes; i. e., the external rays emanating from an object must, by their intersection at the nodal point, form an angle of at least 5 minutes. Snellen has made his test-types, for determining the range of accommodation, in accordance with this fact. The

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* The following symbols and abbreviations are used in the course of this dissertation for the sake of brevity:

V acuteness of vision.
A or $\frac{1}{A}$ range of accommodation.
∞ infinite distance.
p punctum proximum (near point).
r punctum remotisimum (far point).
P distance from *p* to eye.
R distance from *r* to eye.
E emmetropia.
H hypermetropia.
M myopia.
h horizontal meridian.
v vertical meridian.
+ (used in connection with a lens) indicates positive power (convex lens).
— indicates negative power (concave lens).

letters are square and their size increases at a definite ratio, so that each number is seen under an angle of 5′ at a distance corresponding in feet to the number of the type. Thus, No. 1 is seen by a normal eye up to a distance of one foot, No. 2 at 2 feet, and so on.

If the eye is not possessed of normal acuteness of vision, it will require to see the letters under a greater angle than 5′. No. XX (Fig. 5) cannot be read at 20 feet, but only, perhaps, at 15 or 10 feet.

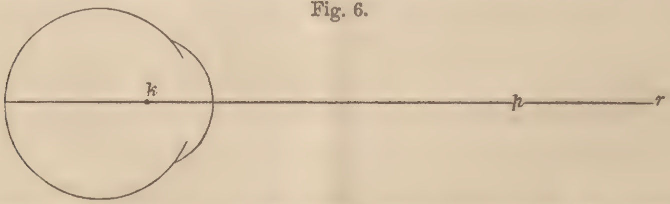
Fig. 5.

Snellen's Test Types, No. XX.

To calculate the degree of acuteness of vision, (V) divide the distance at which No. XX can be recognized (d) by the distance at which it appears under an angle of 5′ (D) thus : $V=\frac{d}{D}$.

If No. XX is visible at 20 feet; d and D are equal and the acuteness of vision is normal, $V=\frac{20}{20}=1$. If No. XX is only visible within 10 feet, $V=\frac{10}{20}=\frac{1}{2}$. The distance of p from the nodal point of the eye (P) and the distance of r from the same point (R) being known, the range of accommodation (A) may be easily found by the formula $\frac{1}{A}=\frac{1}{P}-\frac{1}{R}$, which is thus explained by Donders, its inventor: "In this formula, A is the focal length of a lens, which

Fig. 6.



gives a direction to the rays from the nearest point of distinct vision p, as if they came from the farthest point r. The subjoined figure (6) illustrates this. The eye in the condition of rest is

accommodated for the distance $rk=R$; in the strongest tension of accommodation for the distance $pk=P$. In the former case the rays diverging from r are united on the retina, in the latter those diverging from p. In accommodation the eye must, therefore, be so altered that the rays proceeding from p, in the vitreous humor acquire a direction equal to that of the rays proceeding from r in the non-accommodated eye. This can be affected by placing an auxiliary lens in k, and we may thus imagine the eye away, and suppose that the anxiliary lens in k is in the air. The lens now represents the accommodation of the eye, and its power the range of accommodation. Its focal distance, A, is found by the formula mentioned: $\frac{1}{P}-\frac{1}{R}=\frac{1}{A}$. Consequently A is the focal distance of the auxiliary lens, of which the eye avails itself in accommodation, and as the power of a lens is inversely proportional to its focal distance, $\frac{1}{A}$ or $1 : A$ expresses the range of accommodation. It is convenient to represent the value of A in Parisian inches, especially as the focal distance of lenses is usually stated in the same, and this applies, also, more particularly to spectacles." (Donders, p. 30). To illustrate this let us suppose that in a given case $R=\infty$, $P=5$ inches by the formula $\frac{1}{A}=\frac{1}{P}-\frac{1}{R}$ we should obtain $\frac{1}{A}=\frac{1}{5}-\frac{1}{\infty}=\frac{1}{5}$. Hence the range of accommodation would be equal to a convex lens of 5 inch focus.

In cases where the patient is unable to read No. XX at 20 feet, the greatest distance at which he can read No. 1 must be ascertained. If he reads it at 10 inches $R=\frac{1}{10}$, and if he can read it no nearer than 5 inches $P=\frac{1}{5}$. By the same formula we have $\frac{1}{A}=\frac{1}{5}-\frac{1}{10}=\frac{1}{10}$. The power of accommodation in this case is only equal to a convex lens of 10 inch focus.

A convenient method for testing the range of accommodation is to place a strong convex lens before the eye and request the patient to read No. 1, Snellen. If No. 6 convex be placed before a normal eye, whose far point lies at infinite distance, r will be found to lie at 6 inches in front of the lens, (No. 1 Snellen can be read at no greater distance,) for the lens will render rays parallel emanating from a point 6 inches in front of it. The near point will lie at about $2\frac{2}{3}$ inches in front of the lens. This point, how-

ever, varies with the age of the patient. The far point (r') and the near point (p') thus found, bear the same relation to each other as the real points r and p, as their distances are diminished in an equal ratio. The range of accommodation is, therefore, easily found by the formula $\frac{1}{A}=\frac{1}{P}-\frac{1}{R}$. If r' lies at 6 inches and p' at 3 inches, $\frac{1}{A}=\frac{1}{3}-\frac{1}{6}=\frac{1}{6}$.

Besides the absolute range of accommodation described above, which exists when each eye is examined separately, it is neceessary to distinguish two other ranges, the binocular and the relative. The binocular range is sufficiently explained by its name. The relative range is the degree of accommodation which exists while the convergence of the visual lines remains in a fixed state.

ANOMALIES OF REFRACTION AND ACCOMMODATION.

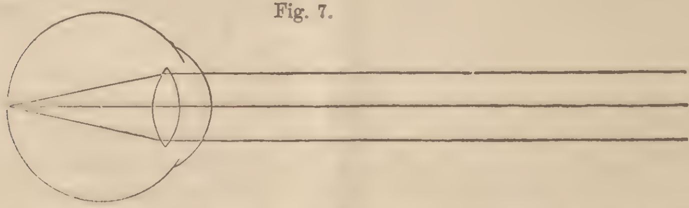
By refraction of the eye is understood its refraction while at rest, independent of muscular action. Its degree is ascertained to a nicety by an examination made while the muscles of accommodation are paralyzed. In a state of rest the eye is adjusted for its farthest point.

Accommodation is the voluntary action whereby the eye becomes adjusted to a nearer point than when at rest.

"Refraction is dependent on the anatomical condition of the component parts of the eye; accommodation, on the contrary, depends upon the physiological action of muscles."—*Donders.*

The refraction of the eye is considered normal, when, the eye being in a state of rest, parallel rays are united exactly on the anterior surface of the layer of rods and cones of the retina. Such an eye is called *emmetropic.* Its far point lies at infinite distance. (Fig. 7).

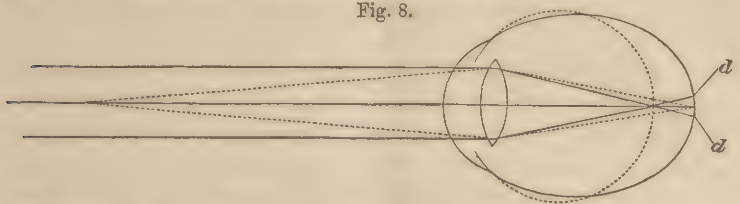
Fig. 7.



The eye may deviate from the emmetropic condition in two ways. Its principal focus may lie in front of the retina, or behind it. In the former case *myopia* exists, and divergent rays only will be

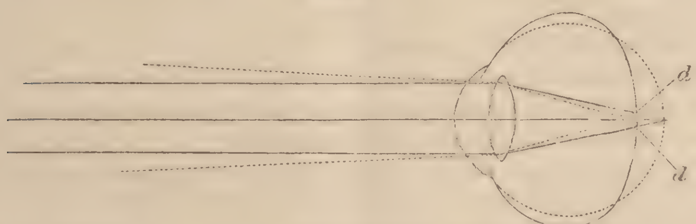
united upon the retina (Fig. 8). Parallel rays are brought to a focus in front of the retina. Circles of diffusion (*d d*) are formed upon the retina, and vision is consequently indistinct.

Fig. 8.



In the latter case *hypermetropia* exists and only convergent rays are brought to a focus upon the retina (Fig. 9). Parallel rays are brought to a focus behind the retina, and circles of diffusion (*d d*) are formed upon the retina.

Fig. 9.



It will be seen from this that myopia and hypermetropia are exactly opposite conditions of the eye.

The refraction may vary in the different meridians of the same eye. It may be emmetropic in the horizontal meridian, and myopic or hypermetropic in the vertical, and *vice versa*, or differences in the degree of the same anomaly may exist. This asymmetry is termed astigmatism.

The anomalies of accommodation are dependent upon the following conditions :—Loss of the lens, weakness, paralysis, or spasm of the ciliary muscles.

Deficiency in the range of accommodation dependent upon either of the before cited causes, if extensive, should, as far as possible, be remedied by glasses.

Presbyopia is the diminution of the power of accommodation dependent on advanced life. In it the near point recedes farther and farther from the eye with increasing years. In pure presbyopia the far point is unaffected. Quite late in life, however, a slight degree of hypermetropia is acquired from the flattening of the lens.

Presbyopia is chiefly dependent upon changes in the structure of the lens, which in old age becomes more firm, resisting in a greater or less degree the action of the ciliary muscle.

The retrocession of the near point commences as early as the tenth year, but is not usually recognized until about the fortieth year. An eye is considered presbyopic as soon as the near point has receded to a greater distance from the eye than 8 inches. Presbyopia may, therefore, co-exist with myopia of less than $\frac{1}{8}$, but it manifests itself later in life. Presbyopia co-exists with hypermetropia in cases where, the hypermetropia having been corrected by means of glasses, the near point lies at a greater distance than 8 inches.

In pure presbyopia the normal acuteness of vision and normal range of accommodation may in all cases be restored by means of proper convex glasses. The range of accommodation in presbyopia is determined by the same method as in emmetropia.

The opinion is very general that the use of convex glasses should be deferred as long as possible. This is a very grave error, and I am forced to believe that pride often contributes largely to the entertainment of this opinion. The overtaxing of the accommodation in the endeavor to see small objects hastens the progress of the affection, and at the same time wearies the patient unnecessarily. There can be no question of the propriety of furnishing patients with suitable glasses as soon as they are in the slightest degree annoyed or inconvenienced by presbyopia. We often see cases where at 50, 60, and occasionally even at 70 years of age, a person is able to read at a distance of 10 or 12 inches without the aid of glasses. Such people always consider themselves lucky exceptions to the general rule, and usually attribute it to their good judgment in the management of their eyes, more particularly in never having indulged in the use of glasses. In point of fact such people owe their immunity from the use of glasses to being slightly myopic, as may be proved by requesting them to read No. xx Snellen at 20 feet. They will not be able to do so except with the assistance of concave glasses of $\frac{1}{50}$ to $\frac{1}{36}$. Myopia may always be diagnosed in cases where spectacles have not been required for distinct vision of near objects at or soon after the fortieth year. Donders, after treating of this subject, says: "The more I investigate the subject, the more fully I am convinced that at a given time of life the range of accommodation is an almost law-determined quantity." I must differ with him so far as to claim that presbyopia

progresses much more rapidly when the eye is overtasked by poor artificial light.

The degree of presbyopia is easily determined after having once decided upon a definite distance (8 inches) as its commencing point. Thus if the presbyopic near point (p_2) lies at 16 inches $P_2 = \frac{1}{8} - \frac{1}{16} = \frac{1}{16}$, and ought, *ceteris paribus*, to be corrected by convex glasses of 16 inch focus. In practice, however, these glasses are found to be somewhat too strong, for, owing to the increased convergence of the optic axes, they will bring the near point closer to the eye than 8 inches. The weakest glasses that will enable the patient to read, easily, No. 1 Snellen at 12 inches are usually sufficient, in cases where no hypermetropia exists, and even these may not be tolerated at first. If the range of accommodation be good p may usually be brought to 8 inches, but if it be much diminished, p must not lie nearer than 10 or 12 inches.

MYOPIA.

In myopia the far point is more or less approximated to the eye. Parallel rays are not united upon the retina but in front of it, consequently each pencil of rays forms a circle of diffusion on the retina (Fig. 8, *d d*), and distant vision is rendered indistinct. Objects situated at a definite finite distance only will be distinctly seen. It was formerly supposed that myopia was dependent upon an increase in the convexity of the cornea. This is now known to be erroneous. Indeed it has been found that, as a rule, the cornea is less convex in myopic than in emmetropic eyes.

The most frequent cause of myopia is an abnormal increase in the length of the eyeball in its antero-posterior axis. It is often attended with posterior staphyloma, which should always be suspected and sought for, by means of the binocular opthalmoscope, in cases where the existing myopia exceeds $\frac{1}{6}$, as its presence is of the greatest moment to the patient. The manner of finding the far point has been already explained. It only remains necessary for me now to briefly explain the method of ascertaining the existence and approximate degree of myopia, in cases where the statements of the patient are not trustworthy. This is accomplished by means of the opthalmoscope. On examining a myopic eye in the erect image, (with the mirror merely) if the observer fixes his attention upon the optic disc or retinal vessels and moves his head in any direction the image will appear to move in the opposite direction. In emmetropia the image remains fixed, and in hypermetropia it moves in the same direction as the observer's head. To obtain an

erect image of a myopic eye it is necessary to place a concave lens behind the mirror and bring it within the focal distance of the observed eye. The lens renders the convergent rays from the myopic eye parallel, and the fundus of the eye is seen as from an infinite distance.

The opthalmoscope reveals other peculiarities in the myopic eye, but the limits of this dissertation will not allow of their consideration.

Myopia is sometimes confounded with amblyopia (weakness of vision) as persons affected with amblyopia habitually bring small objects near to the eye in order to obtain larger and more clearly defined retinal images. The diagnosis between the two is easy. In amblyopia the patient is unable to distinguish very small objects at any distance. Moreover, vision is not improved by concave glasses as is the case in myopia, but rendered less distinct, as the glasses diminish the size of the retinal images. Myopia is a disease peculiar to civilization. It is most frequent in the higher and literary circles, and rarely met with in sailors or agriculturists. The principal cause of the disease is the excessive use of the eyes for near objects, conjoined with insufficient light, and a stooping posture, which is so commonly assumed by students. The same causes make the disease progressive. In looking at near objects the optic axes are strongly converged. This causes increased pressure upon the eye, through the medium of the recti muscles, which, if long continued, results in congestion of its inner tunics and increased pressure of the ocular fluids. Bulging of the posterior pole, (that part unlike the rest of the eye receiving no support from the muscles) and consequent lengthening of the antero-posterior axis of the eye, is the final result of this pressure. It is also probable that after the eye has been so constantly accommodated for near objects, that the ciliary muscle may become more or less permanently contracted, and that the lens losing a part of its elasticity, remains abnormally convex. Myopia is hereditary to a great extent, and this hereditary principle is accumulative.

The popular belief that myopia diminishes with increasing age, and more surely where the use of glasses is not indulged in, is erroneous. We have already shown that myopia consists in the approximation of r to the eye, and that the effect of age is to diminish the range of accommodation by removing p farther from the eye. As the causes which give rise to myopia are equally favorable to its farther development, by removing the principal of

these causes, (the convergence of the optic axes) we necessarily retard the progress of the disease. This end is accomplished by the judcious use of biconcave lenses or negative menisci, which render parallel rays divergent.

In the selection of glasses for myopes, the weakest that will correct the myopia should be chosen. Too strong glasses are often productive of much injury. If r lies at 7 inches $M=\frac{1}{7}$ and should, theoretically, be corrected by glasses of $-\frac{1}{7}$ but, as the convergence of the optic axes prevents the eye from accommodating itself for its far point, the apparent myopia is greater than the real, and concave 7 is too strong. To ascertain the exact power required, give the patient concave 8 and request him to read No. XX at 20 feet. Let us suppose that he can do so, but that the letters appear indistinct. Concave 60 placed before the spectacles renders the object less distinct, while convex 60 placed before the spectacles renders the letters clear and well defined. Convex 50 impairs the vision. From this we know that the glass is yet too strong by $\frac{1}{60}$. To find the proper power we must deduct convex 60 from concave 8, thus : $\frac{1}{8}-\frac{1}{60}=\frac{1}{9\frac{1}{4}}$ nearly; remembering the rule to give the weakest glass that will correct the myopia, he is furnished with concave $9\frac{1}{2}$, and we find that neither positive nor negative glasses placed before it make any improvement.

It is often necessary to furnish patients with glasses for reading at a distance of 18 inches or 2 feet. In cases where the myopia is considerable or the accommodation poor, it is generally best to furnish them with glasses that bring r to that distance, rather than to wholly neutralize the myopia, which would greatly decrease the size of the retinal images. Suppose a patient requires concave 9 for distance, for objects at 18 inches he will require $-\frac{1}{9}+\frac{1}{18}=-\frac{1}{18}$, and for reading at 12 inches he will require $-\frac{1}{9}+\frac{1}{12}=-\frac{1}{36}$. When the myopia is slight, the range of accommodation good, and the eye otherwise healthy, neutralizing glasses may be worn both for distant and near objects. Donders thinks this is even desirable and that it greatly retards the progress of the disease, particularly in youth. He says: "When persons with moderate degrees of myopia have in youth accustomed themselves to the use of neutralizing spectacles, the eyes are in all respects similar to emmetropic eyes, and the myopia is, under such circumstances, remarkably little progressive. I am acquainted with numerous examples of this, even among those of my friends who have passed their lives in study.

Glasses of $-\frac{1}{10}$ adopted at seventeen years of age, are often still sufficient at forty-five years, both for seeing acutely at a distance and for ordinary close work. Not until the age at which emmetropes need convex spectacles, and often even some years later, do the neutralizing spectacles become rather too strong for close work, and it is desirable to procure somewhat weaker ones, which, with the narrower pupil peculiar to that time of life, are now nearly sufficient for distance also. In order to obtain all the advantages of concave glasses the myope must begin early with them. If the myopia amounts only to a fourth or a third of the range of accommodation, we may immediately wholly neutralize it. If it amounts to more we must usually begin with weaker glasses, and replace them at the end of six months with stronger ones."*

To test the range of accommodation in a myope, glasses should be given him which exactly neutralize the myopia (No. XX being distinguished at 20 feet), with these r will lie at ∞. Then ascertain how near he can read No. 1 with ease. Let us suppose that he reads No. 1 at 5 inches by the formula $\frac{1}{A}=\frac{1}{P}-\frac{1}{R}$ we obtain $\frac{1}{A}=\frac{1}{5}-\frac{1}{\infty}=\frac{1}{5}$. It is important in myopia that each eye be examined separately as well as the two together, for there occasionally exists a marked difference in the degree of myopia in the two eyes, which may demand glasses of different foci. In such cases, if the difference be considerable, it is not usually advisable to furnish each eye with the glass that exactly neutralizes its myopia, for as a rule such spectacles render vision confused, on account of the difference in the size of the two retinal images. In a few cases the patient, after a little practice, is enabled to see clearly with them, and then their use is admissable and even advantageous, as it enables him to estimate distances.† If the patient be annoyed by the difference in the size of the two images, each eye must be furnished with the glass appropriate for the least myopic eye; or the difference of refraction in the two may be partially neutralized by furnishing the least affected eye with its appropriate glass, and the other with one of a somewhat higher power. Thus if the myopia of one eye equals $\frac{1}{12}$ and the other $\frac{1}{6}$ the glasses may be respectively $-\frac{1}{12}$ and $-\frac{1}{8}$ or $-\frac{1}{9}$. The circles of diffusion are thereby diminished, and a certain degree of binocular vision secured. It has been proposed, in

* Donders p. 421.

† It is a singular fact, that when seen by one eye only, a die from which medals are struck, appears in relief like the perfected medal.

such cases, when the sight of the two eyes is equally good, to furnish each eye with the glass which lies midway between the two degrees of myopia. Thus, myopia of one eye being $\frac{1}{12}$ and of the other $\frac{1}{6}$, it would be advised to prescribe $-\frac{1}{8}$ for both eyes, but such spectacles would evidently be of no use to either eye.

HYPERMETROPIA.

Hypermetropia is the exact opposite of myopia. In it the refractive power of the eye is too low, or the optic axis too short, therefore, when the eye is in a state of rest parallel rays are united behind the retina and circles of diffusion are formed upon the retina (Fig. 9, *d*, *d*.) In slight cases of hypermetropia, where the eye is otherwise healthy, the defect is overcome by the power of accommodation. In high degrees, or if the accommodation be poor, the patient will not be able to see clearly at any distance. We must, therefore, furnish him with convex glasses of sufficient power to bring parallel rays to a focus upon the retina. Even stronger ones may be required for near objects when the range of accommodation is short.

Several forms of hypermetropia are recognized. They are divided first into two primitive classes, the original and the acquired. The latter is, in nearly all cases, due to senile changes in the lens, which in old age possesses less refractive power than in youth. Absence of the lens will, of course, give rise to excessive hypermetropia. Original hypermetropia is subdivided into manifest (Hm.) and latent (Hl.) To determine the presence of hypermetropia ascertain if the patient can read No. XX at 20 feet, if he can do so with ease, try whether he can do the same with convex glasses. If he can, he has hypermetropia, and the number of the strongest glass with which he can see distinctly, will indicate the degree of manifest hypermetropia. The degree of real hypermetropia is usually much greater than that of the manifest, for the patient is unable at once to wholly relax the accommodation, even for distant objects, after it has been so long exerted. To determine the real degree of hypermetropia it is necessary to paralyze the accommodation and re-examine. The second examination developes the latent hypermetropia. In hypermetropia, as in myopia, each eye should be examined separately. In young people with good accommodation, slight degrees of hypermetropia often remain unnoticed until the age of 20 or 25, when symptoms of asthenopia arouse our suspicions of its existence. Hypermetropia is termed facultative when the patient is able to see well (with parallel optic

axes) at a distance both with and without convex glasses. Persons affected with it can generally read small print without glasses while young, but presbyopia sets in early, and symptoms of asthenopia soon manifest themselves. Hypermetropia is termed relative when the patient can see well at a distance and near at hand without convex glasses, only by converging the optic axes for a nearer point than that at which the object is situated, thereby producing a periodic convergent squint. In such cases vision is always poor. Hyper metropia is termed absolute when vision is indistinct for all distances even with the strongest effort of accommodation and greatest convergence of the optic axes. It is seldom met with except in advanced life. To find the range of accommodation in a hypermetropic eye, first change it into a normal one by furnishing it with a glass that will bring parallel rays to a focus upon the retina with almost no effort of accommodation, and then find the nearest point at which No. 1 can be distinctly seen. It is usual, in testing the near point, to employ a glass, the index power of which lies between those required for distance before and after the instillation of atropia. Thus, if before the instillation of atropia the patient requires convex 20 for distance, and 10 after it, convex 16 would be the proper glass with which to try the near point. No. 10, which neutralizes the real hypermetropia, would be too strong, for the patient, so long accustomed to strain his accommodation, would be unable, at once, to command the far point with so high a power. An eye with $Hm=\frac{1}{20}$ can see distinctly at a distance with $+16$ without much effort. Therefore r will lie at ∞. Now suppose p be found to lie at 7 inches, by the formula $\frac{1}{A}=\frac{1}{P}-\frac{1}{R}$ we obtain $\frac{1}{A}=\frac{1}{7}-\frac{1}{\infty}=\frac{1}{7}$. The result obtained by this method is not mathematically exact, but sufficiently so for all practical purposes.

As has been already stated, hypermetropia is the most frequent cause of asthenopia. Asthenopia in hypermetropes is due to the over-straining of the accommodative apparatus in the attempt to unite parallel and divergent rays upon the retina. It can be cured only by neutralizing the hypermetropia.

Covergent strabismus is often dependent upon the existence of hypermetropia, and, in such cases, when corrected by an operation, it will surely return if the hypermetropia be disregarded.

In what cases and to what extent is it best to neutralize hypermetropia? This is a question of the greatest importance. In facultative hypermetropia glasses should never be prescribed for distance, for the patient, by a slight effort of accommodation, sees

well without them, and by their constant use he would soon lose that power. In cases where asthenopia exists glasses must be given for reading, sewing, &c., that are somewhat stronger than those which correct the manifest hypermetropia. If they are too strong at first, weaker ones must be employed and the strength gradually increased until the asthenopia disappears. In relative and absolute hypermetropia spectacles should be worn both for distant and near objects, for in such cases all vision is indistinct. It is generally best to commence with glasses which neutralize the manifest hypermetropia. It is sometimes necessary to give weaker glasses at first for distance, and gradually increase their strength. In cases where there is co-existent presbyopia, stronger glasses must be prescribed for near objects.

ASTIGMATISM.

Astigmatism consists of a difference in the degree of refraction in the different meridians of the same eye. Nearly all eyes are, strictly speaking, slightly astigmatic, for the focal distance of the normal eye is generally shorter in the vertical than in the horizontal meridian. This explains why a ray of light, passing through a minute round opening in a dark screen, appears as a round point only when seen from a certain distance. When carried farther off it is elongated in a vertical direction, and when brought nearer to the eye, in a horizontal direction. Figures 10 and 11 will serve to elucidate this fact.

Fig. 10.

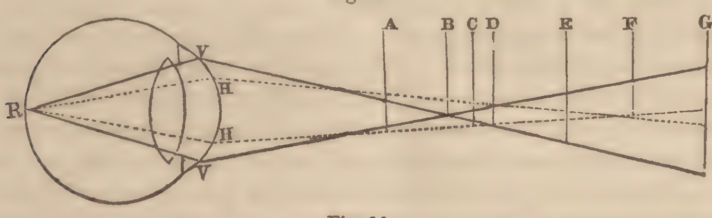
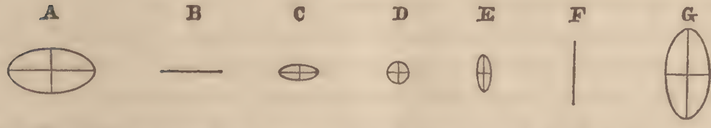


Fig. 11.



Let Fig. 10 represent an eye whose shortest radius of curvature is in the vertical meridian and the longest in the horizontal. The anterior focal point of the eye in the vertical meridian is situated at B, and in the horizontal meridian at F. The space between

these two points is called the focal interval. Vertical rays emanating from a luminous point situated at B will be united on the retina, but as the focal point of the eye for horizontal rays lies at F, such rays emanating from a point of light situated at B will not be brought to a focus on the retina but behind it, consequently the retinal image will have the form of a horizontal line (Fig. 11 B.) In the same manner a point of light situated at F, will appear as a vertical line (Fig. 11 F.) The vertical meridian of the retinal image increases and the horizontal decreases in direct ratio as the object is carried from B to F, and *vice versa*. The forms which the retinal image of a point of light assumes, when situated at different points within the focal interval, are seen in Fig. 11. The letters correspond to those of Fig. 10. From the foregoing it will be seen that fine vertical lines can be seen at a greater distance from the eye than horizontal lines, while the latter can be seen closer than the former. At B horizontal lines will appear perfectly distinct, for at that distance aberration exists only in the horizontal meridian. The diffusion images, therefore, will have the form of short horizontal lines, the overlapping of which can cause no confusion of the object, as it is itself a horizontal line. For the same reason vertical lines are seen distinctly at F. General vision is most distinct when the object is situated at D, for at that point only small circles of diffusion are formed upon the retina. The point D is the mathematical near point of the eye, to which reference has already been made. Although the maximum of curvature generally corresponds to the vertical meridian and the minimum of curvature to the horizontal meridian, this does not always obtain. The maximum and minimum of curvature may correspond to any two opposite meridians. When the aberration is due to a difference in the refractive power of the two principal meridians, it is termed regular astigmatism; when due to a difference in the refraction of different parts of the same meridian, it is called irregular astigmatism. The former depends upon irregular curvature of the cornea, and is to be remedied by cylindrical glasses in the manner to be hereinafter explained. The latter depends, generally, upon a peculiarity in the structure of the lens, and cannot in such cases be corrected, except by the removal of the lens, when the case is converted into one of simple absolute hypermetropia.

The slight degree of regular astigmatism, which exists in the normal eye, does not materially impair the vision. An eye is con-

sidered to be astigmatic, only when the degree of aberration is sufficiently great to render vision indistinct by the overlapping of the circles of diffusion. Such an eye can see neither near or distant objects clearly, nor is vision much improved by spherical lenses in cases where myopia or hypermetropia co-exists with the astigmatism.

The diagnosis of astigmatism is generally easy, and to be made as follows: First, examine carefully the acuteness of vision by ascertaining which number of Snellen's test-types the patient can read at 20 feet. If he cannot read No. XX try the effect of convex and concave spherical lenses; if he is still unable to decipher it the presence of astigmatism must be suspected. The situation of the two principal meridians of the eye (i. e. the maximum and minimum of curvature) may be found by directing the patient to look at a small distant point of light. If the eye is astigmatic this point will not appear round but elongated in a certain direction, accordingly as the object is nearer or farther off than the point for which the eye is accommodated. In conducting this examination, it is customary to place, at a distance of 12 to 16 feet in front of the patient, a large dark screen with a round opening, varying from 2 to 4 millimètres in diameter, for the transmission of light. By moving the screen backwards and forwards in front of the patient the principal meridians are readily found. Their position is, however, more accurately and easily determined by means of Green's test objects, three of which are represented in Figures 12, 13 and 14.

Fig. 12.

The first consists of a circle traversed by a set of twelve triple radiating lines, with figures at their distal extremities, corresponding to those on the dial of a watch. Each primitive line is equal in width to those employed in the construction of No. XX of Snellen's test-types. The inner circle is 9 inches in diameter. The

other objects are simply modifications of the first. For a full description of them and their use see the Transactions of the American Ophthalmological Society for the year 1868. All the lines should be distinctly seen at a distance of 20 feet. If they

Fig. 13.

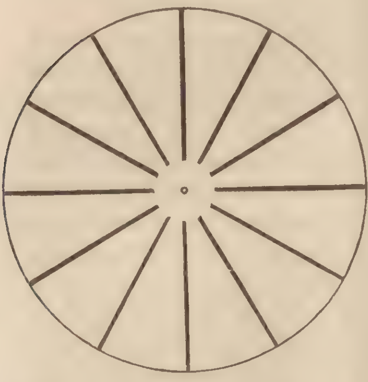
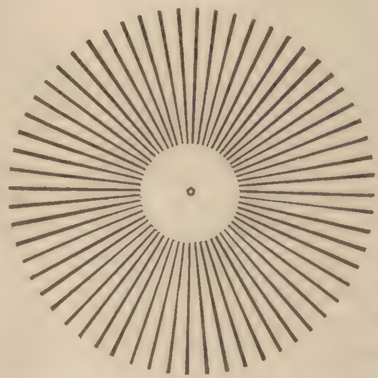


Fig. 14.



are, with or without the aid of spherical glasses, the patient is not astigmatic, but if, on the other hand, the lines in one meridian only are sharply defined, astigmatism exists, and the direction of the distinct lines corresponds to one of the principal meridians of the eye. To ascertain the nature and degree of astigmatism, it is only necessary to find the weakest concave or strongest convex lens which will enable the patient to see all the lines with equal distinctness. If a concave lens is required it is a case of myopic astigmatism; if a convex, of hypermetropic astigmatism. The power of the lens will, in each case, indicate the degree of apparent astigmatism. In some cases of hypermetropic astigmatism a portion of the aberration is concealed by the effort of accommodation. It is, therefore, necessary to paralyze the accommodation in order to determine its real degree. Dobrowski, of St. Petersburg, claims that regular astigmatism may be assimilated or temporarily overcome by irregular spasmodic action of the ciliary muscle, the convexity of the lens being unduly increased in some one meridian. Several other methods have been devised for the determination of this anomaly, but those already explained are sufficient for our purpose.

Regular astigmatism is either simple, compound, or mixed. In the simple form the eye in one principal meridian is emmetropic, and in the other myopic or hypermetropic. If such a case be examined with the stenopæic apparatus, and the slit turned in the di-

rection of the normal meridian, vision will be perfect, but if the slit be turned in the direction of the astigmatic meridian, a convex or concave spherical lens will be required. Simple astigmatism is sub-divided into simple myopic astigmatism (Am) and simple hypermetropic astigmatism (Ah).

In compound astigmatism myopia or hypermetropia exists in both principal meridians, but in different degrees. Here we must also distinguish two forms. 1. Compound myopic astigmatism (MAm) in which myopic astigmatism is superadded to myopia, and, 2. Compound hypermetropic astigmatism (HAh) in which hypermetropic astigmatism is superadded to hypermetropia.

For example, let us suppose that in the vertical meridian $M=\frac{1}{10}$ and in the horizontal $\frac{1}{30}$. There would then exist $M\frac{1}{30}$ common to all the meridians and in addition, in the vertical meridian, $Am=\frac{1}{10}-\frac{1}{30}=\frac{1}{15}$. The condition of the eye is expressed thus: $M\frac{1}{30}+Am\frac{1}{15}$. Mixed astigmatism is very rare. In it one principal meridian is myopic and the other hypermetropic. It exists in two forms. 1. With predominant myopia (Amh). 2. With predominant hypermetropia (Ahm). Astigmatism may be congenital or acquired. In the majority of cases it is congenital, and often hereditary. Congenital astigmatism is usually regular and exists in both eyes, although, perhaps, in different degrees. It is most frequent in hypermetropia. Acquired astigmatism is nearly always dependent upon morbid changes in the curvature of the cornea; the result of inflammatory process or the irregular union of the incision after cataract and similar operations. It can be very imperfectly, if at all, corrected.

As has already been stated, cylindrical lenses possess the power of refraction in but one of the principal meridians. It follows from this that regular astigmatism may be corrected by means of cylindrical glasses. The axis of a convex cylindrical lens, employed in the treatment of astigmatism, must correspond exactly to the highest refracting meridian of the eye, and that of a concave, to the lowest refracting meridian. The slightest deviation from the above rule will render vision confused. Nachet's trial spectacle frames are very convenient in the adapting of cylindrical glasses. They are round, to permit the rotation of the glasses. The upper half of each circle is divided into degrees numbered from 0 to 180°. The meridian of greatest curvature is marked in each glass. The angle of inclination of the principal meridian can, therefore, be read off from the frames, after the proper adjustment of the

lens. Three kinds of lenses are required for the correction of the different forms of astigmatism, viz: Plano-cylindrical, bi-cylindrical, and spherico-cylindrical. I will now illustrate, by a few examples, the manner of selecting cylindrical glasses for the correction of astigmatism. Let us suppose a case in which E exists in one principal meridian ($R = \infty$) and in the other $M = \frac{1}{10}$ ($R = \frac{1}{10}$), consequently we have $Am = \frac{1}{10} - \frac{1}{\infty} = \frac{1}{10}$. The aberration is corrected by a concave cylindrical glass of $9\frac{1}{2}$ inch focus* (written $-\frac{1}{9\frac{1}{2}}c$). Simple hypermetropic astigmatism (Ah) $= \frac{1}{10}$ is corrected by $+\frac{1}{10\frac{1}{2}}c$. Compound myopic astigmatism (MAm) is corrected by concave spherico-cylindrical glasses, thus: MAm composed of $M\frac{1}{20} + Am\frac{1}{10}$ is corrected by $-\frac{1}{20}s$ combined with $-\frac{1}{10}c$,† (written $-\frac{1}{20}s \subset\!\supset -\frac{1}{10}c$). Compound hypermetropic astigmatism (HAh) requires convex spherico-cylindrical glasses, thus: HAh composed of $H\frac{1}{20} + Ah\frac{1}{10}$ is corrected by $\frac{1}{20}s \subset\!\supset \frac{1}{10}c$. Mixed astigmatism (Amh and Ahm) requires bi-cylindrical glasses, having one convex and one concave surface, the axes of the two forming a right angle thus: Amh composed of $M\frac{1}{10} + H\frac{1}{20}$, is corrected by $+\frac{1}{20}c$ and $-\frac{1}{10}c$ with their axes at right angles, (written $\frac{1}{20}c \ulcorner -\frac{1}{10}c$.) And Ahm composed of $H\frac{1}{10} + M\frac{1}{20}$ by $\frac{1}{10}c \ulcorner -\frac{1}{20}c$. The foregoing examples explain the method of correcting, at once, both the astigmatism and ametropia. In other words, of converting the eye into an emmetropic one. This is not always desirable, for whilst the correction of astigmatism always improves vision, the use of very strong glasses interferes with the combined action of the ciliary and internal recti muscles in the effort of accommodation as well as greatly to affect the size of the retinal images. If it be desired to correct the astigmatism and retain a definite degree of myopia it is simply necessary to deduct the desired degree of myopia from the reflective power of the two principal meridians, and then correct the remaining ametropia. Examples: E exists in the principal *h* meridian, and $M = \frac{1}{10}$ in the *v*. We wish to obtain $M\frac{1}{20}$. De-

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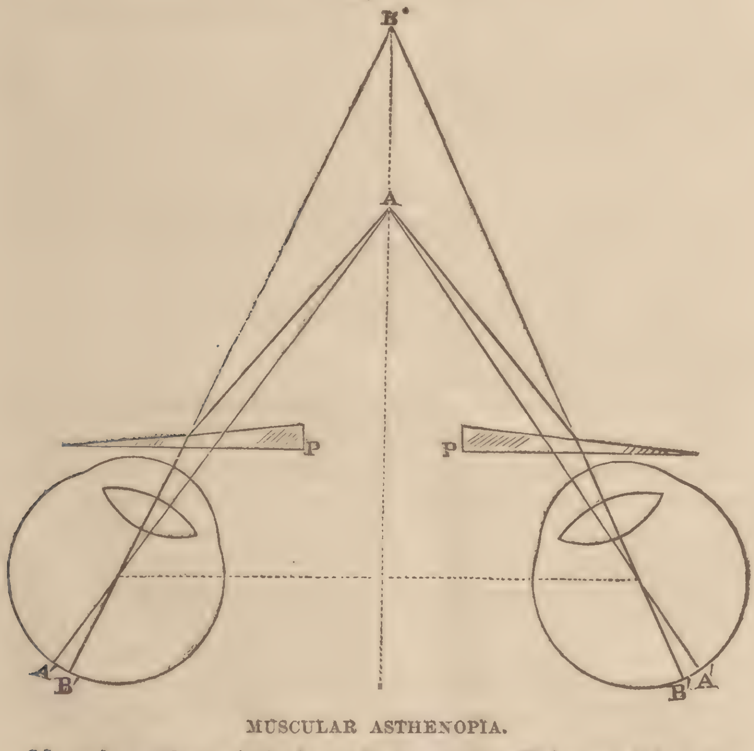
* As the lens is placed about $\frac{1}{2}$ inch in front of the nodal point of the eye, it is necessary, except where the degree of aberration is very slight, to deduct $\frac{1}{2}$ inch from the focal distance of concave lenses, and add $\frac{1}{2}$ inch to that of convex lenses.

† For the sake of simplicity the correction proceeding from the distance between the lens and the nodal point of the eye will be omitted in the examples of compound and mixed astigmatism.

ducting $M\frac{1}{20}$ from the refraction of each meridian, we have in h, $E-M\frac{1}{20}=H\frac{1}{20}$, and in v, $M\frac{1}{10}-M\frac{1}{20}=M\frac{1}{20}$. This is corrected by $\frac{1}{20}c \ulcorner -\frac{1}{20}c$. In h, $M=\frac{1}{20}$, in v, $M=\frac{1}{10}$. We desire $M\frac{1}{20}$. Deducting $M\frac{1}{20}$ we obtain in h, $M\frac{1}{20}-M\frac{1}{20}=E$, in v, $M\frac{1}{10}-M\frac{1}{20}=M\frac{1}{20}$; corrected by $-\frac{1}{20}c$. In h, $H=\frac{1}{6}$, in v, $H=\frac{1}{18}$; we desire $M\frac{1}{18}$, deducting $M\frac{1}{18}$, we obtain in h, $H\frac{1}{6}-M\frac{1}{18}=H\frac{1}{4\frac{1}{2}}$, in v, $H\frac{1}{18}-M\frac{1}{18}=H\frac{1}{9}$ corrected by $\frac{1}{9}s\bigcirc\frac{1}{9}c$. In v, $M=\frac{1}{10}$ in h, $H=\frac{1}{20}$, we desire $M=\frac{1}{20}$, by deduction we obtain in v, $M\frac{1}{10}-M\frac{1}{20}=M\frac{1}{20}$, in h, $H\frac{1}{20}-M\frac{1}{20}=H\frac{1}{10}$ which is corrected by $\frac{1}{10}c \ulcorner -\frac{1}{20}c$.

Irregular astigmatism cannot be corrected by cylindrical glasses but may be partially remedied by stenopæic spectacles which exclude a portion of the irregularly refracted rays.

Fig. 15.



MUSCULAR ASTHENOPIA.

Muscular asthenopia is dependent upon insufficiency of the internal recti muscles. The patient is unable to maintain, for any length of time, sufficient convergence of the visual lines to obtain binocu-

lar vision of near objects. One eye soon falls off, and vision becomes indistinct by reason of the overlapping of the retinal images of two distinct objects. In reading, the letters run into each other. In slight cases this may be remedied by the use of prisms, placed in front of the eye as represented in Fig. 15.

The properties of prisms are to refract rays towards their bases. Therefore rays emanating from A, (Fig. 15) instead of continuing on in a straight line to A′, will be deflected to B′. The object will appear to be situated at B, and the visual line will correspond to the line B B′. In severe cases the action of prisms is insufficient and tenotomy of the external recti must be performed. The decentred glasses of Giraud Teulon act as prisms and are very serviceable in cases of hypermetropia and myopia complicated with slight insufficiency of the recti muscles. Prisms with one convex or concave surface are preferable in extreme cases of insufficiency complicated with slight ametropia.

In conclusion it only remains for me to give a few general instructions for the selection of spectacles. It is necessary, except where prisms are indicated, that the optical centre of the glass should be exactly in front of the pupil. It is also important that the plane of the glasses should form as nearly as possible right angles with the visual lines, because under this condition there is the least aberration. Thus a different form of frame will be required for reading and writing than for out of door use.

Concave glasses should be placed as near to the eye as possible, for the farther they are removed from it, the more they diminish the size of the retinal images.

The use of single eye-glasses, so fashionable at the present day, should not be permitted, for two reasons. The unassisted eye becomes impaired from disuse. The retinal images differing in size, as well as acuteness, it is necessary that one be disregarded. The effort required to accomplish this is in itself a fruitful source of permanent injury.

The best lenses are the French which are cast from the best of glass and then accurately ground and polished. Pebbles, which have been so highly extolled, are inferior to the French glasses in every particular except for durability. On account of their hardness they are not easily scratched. A pebble, to be a perfect lens, must be so cut from the crystal that its axis shall correspond exactly to the primary axis of crystallization. If it be not so constructed, it will give rise to a slight degree of acquired astigma-

tism, which must be overcome by an effort of the accommodation. Were we to examine, by polarized light, a thousand pebbles manufactured for the general market, we should hardly find a perfect one.

As scientific, and I may add conscientious opticians are rare, I will state, as the result of my own experience, for the benefit of my professional brethren, that they can place full confidence in the house of Thaxter & Bro., 139 Washington Street, Boston, who are prepared to promptly furnish all kinds of glasses which any of them may be called upon to prescribe.

In treating a subject of so much importance within the prescribed limits of a dissertation, I have been compelled to omit much that I should otherwise have included. It has, however, been my aim to present such parts of the subject as, in my judgment, are the most important, in as concise and clear a manner as possible. I have avoided abstruse mathematical calculation, and have introduced only such formulæ as I have considered absolutely necessary. My task has been a difficult one, and I cannot flatter myself that I have accomplished it in the manner that I could wish.